NORTHWEST CROPS & SOILS PROGRAM

2018 Hop Germplasm Study

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THE UNIVERSITY OF VERMONT EXTENSION

HOP GERMPLASM STUDY

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Until now, commercial hop (*Humulus lupulus* L.) production has not occurred in the northeast (NE) region of the United States for 150 years. Vermont production peaked in 1860 when the state produced 289,690 kg of dried hops (Kennedy, 1860). A combination of the spread of hop downy mildew, the expansion of production in western states, and prohibition laws from the 1920's contributed to the decline of the 19th century NE hop industry. Today, the Pacific Northwest states of Washington, Oregon, and Idaho remain the dominant hop production sites of the U.S. However, hop production in non-traditional regions is growing and now accounts for over 2% of the total U.S. hop acreage (George, A., 2014). Nationally, there has been recent and unprecedented growth in the craft beer sector which has dramatically increased demand for local hop production.

Hops are native across North America, but European hops and North American landraces were cultivated in northern states from colonization to prohibition. Genetic markers have been used to classify wild NA germplasm (Bassil et al., 2008; Peredo et al., 2010). Wild or naturalized hop plants are in the Vermont landscape, yet they are not grown on a commercial scale. Downy mildew disease pressure is currently one of the biggest concerns in NE hop production. It is possible that naturalized plants have evolved arthropod and disease pest resistance traits allowing them to persist in the environment. It is critical that we begin an active evaluation of existing wild cultivars and emerging hop varietals to explore their potential to increase NE hop production. Furthermore, assessment of germplasm could aid with the discovery of novel and unique hop characteristics and flavor profiles that could be made widely accessible to producers and brewers.

MATERIALS AND METHODS

Wild hop plants were initially collected from eight locations within Massachusetts, New York, and Vermont in the fall of 2016 (Figure 1, Table 1). Multiple rhizome cuttings, approximately 6" in length, were taken from each site, placed in plastic bags and kept in refrigerated storage. Cuttings were occasionally inspected for spoilage and any compromised samples were discarded. After three months of cold storage, the remaining cuttings were planted into 4" pots with Fafard 3B potting media (Kent, New Brunswick) at the UVM greenhouse. Mother plants were produced from the cuttings, maintained at a temperature of 65-70° F and watered as needed by greenhouse staff. Vegetative cuttings were taken from the mother plants to obtain additional plant stock. Cuttings consisted of approximately three nodes and were treated with Hormodin 1™ (Mainland, Pennsylvania) rooting hormone prior to planting into 4" pots with vermiculite. The plants were removed from the greenhouse and placed outside to harden off in mid-May. The plants were transplanted on 20-Jun and 21-Jun 2017 at Borderview Research Farm in Alburgh, VT. Approximately 14-18 individuals from each of the 10 wild hop varieties were planted totaling 163 plants overall. Plants were spaced 3' apart and planted into weed barrier fabric. In 2018, plants were once again propagated and moved into the main hop yard, each variety occupying one 35' plot at 5' spacing for a total of 7 hills per variety. Each plant was strung up on 21-Jun using a single coir string leading up to the top wire.

Figure 1. Map of original wild hop rhizome collection sites.

Table 1. Wild hop varieties and collection location.

Plant	Town, State	Latitude	Longitude
Northfield 001	Northfield, MA	42.715015	-72.465087
Northfield 003	Northfield, MA	42.715015	-72.465087
Peacham 001	Peacham, VT	44.38361111	-72.18638889
Peacham 002	Peacham, VT	44.38361111	-72.18638889
Wolcott 001	Wolcott, VT	44.54416667	-72.41861111
Mount Toby	Sunderland, MA	42.503834	-72.531131
Argyle	Argyle, NY	43.237972	-73.495185
Kingdom 001	Tunbridge, VT	43.9218136	-72.5718315
Kingdom 002	Tunbridge, VT	43.9218136	-72.5718315
Morrisville 001	Morrisville, NY	42.832964	-75.567996

Plants were scouted weekly for pest and beneficial insects beginning in June and continuing through August. Two plants and three random leaves per plant within each plot (variety) were visually inspected. The number of potato leaf hoppers (PLH), hop aphids (HA), two-spotted spider mites (TSSM), and mite destroyers (MD) present on each leaf was recorded.

Due to various growing conditions, hop characteristics, and replanting, higher yields should be expected in subsequent years. In total, all ten varieties were harvested and total yield and quality data were obtained. Plants were harvested using a Hopster 5P (HopsHarvester LLC, Honeoye, NY) hop harvester. The number of individual plants harvested and total cone yield was recorded for each line in the germplasm collection. Cone samples were weighed and dried to determine dry matter content. Cones were also rated in browning severity on a 1-10 scale where 1 indicates low browning and 10 indicates severe browning.

Samples of harvested varieties were vacuum sealed and shipped for analysis. These samples were sent to Alliance Analytical Laboratories (Coopersville, MI) for brew quality analysis as well as minor oil profile and total oil content.

RESULTS

The germplasm lines appeared to differ in their susceptibility to pests (Figure 2). Although these data were not analyzed for statistical differences, it is worth noting the observed differences in pest populations across the varieties. With the exceptionally dry and hot summer in 2018, we noticed much higher populations of two-spotted spider mites compared to other pests. This year, Peacham 002 had the highest levels of TSSM with an average of 4.15 TSSM per leaf whereas Mount Toby had the lowest with only 0.6 TSSM per leaf. Hop Aphids (HA) and Potato Leaf Hoppers (PLH) were both observed in very low numbers throughout the ten germplasm varieties with Wolcott 001 having the highest average of HA per leaf at 0.82 and Peacham 002 at 0.35 pests per leaf for PLH. As we continue the study, we plan to continue scouting germplasm varieties on a weekly basis and hope to observe any difference in cultivar susceptibility.

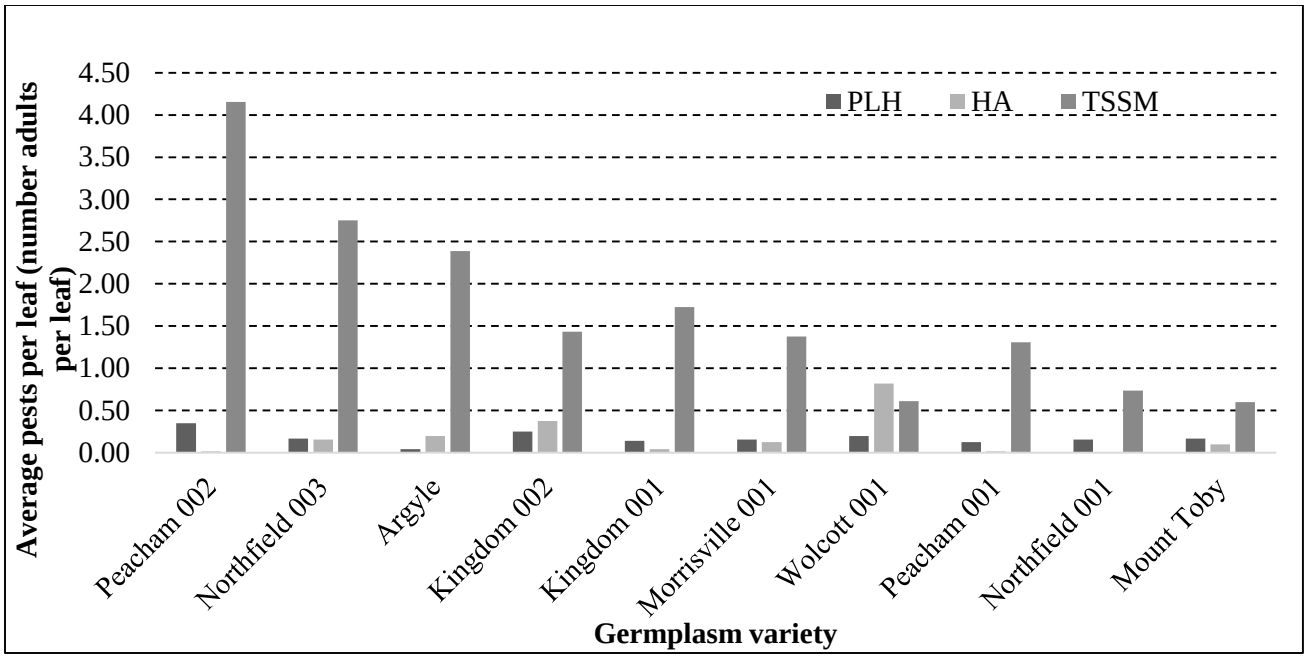

Figure 2. Average number of PLH, HA, TSSM per leaf on each germplasm lines, 2018.

In 2018, we measured the height and side arm lengths of 6 bines out of the 14 bines present in each plot (Figure 3). The length of 4 side arms on each of the 6 bines was measured. Overall, Kingdom 001 had some of the smallest plants with the lowest average plant height and side arm length. Northfield 003 and Argyle had the greatest average bine height at 4.87 m and Peacham 002 had the greatest average side arm length at 58.2 cm.

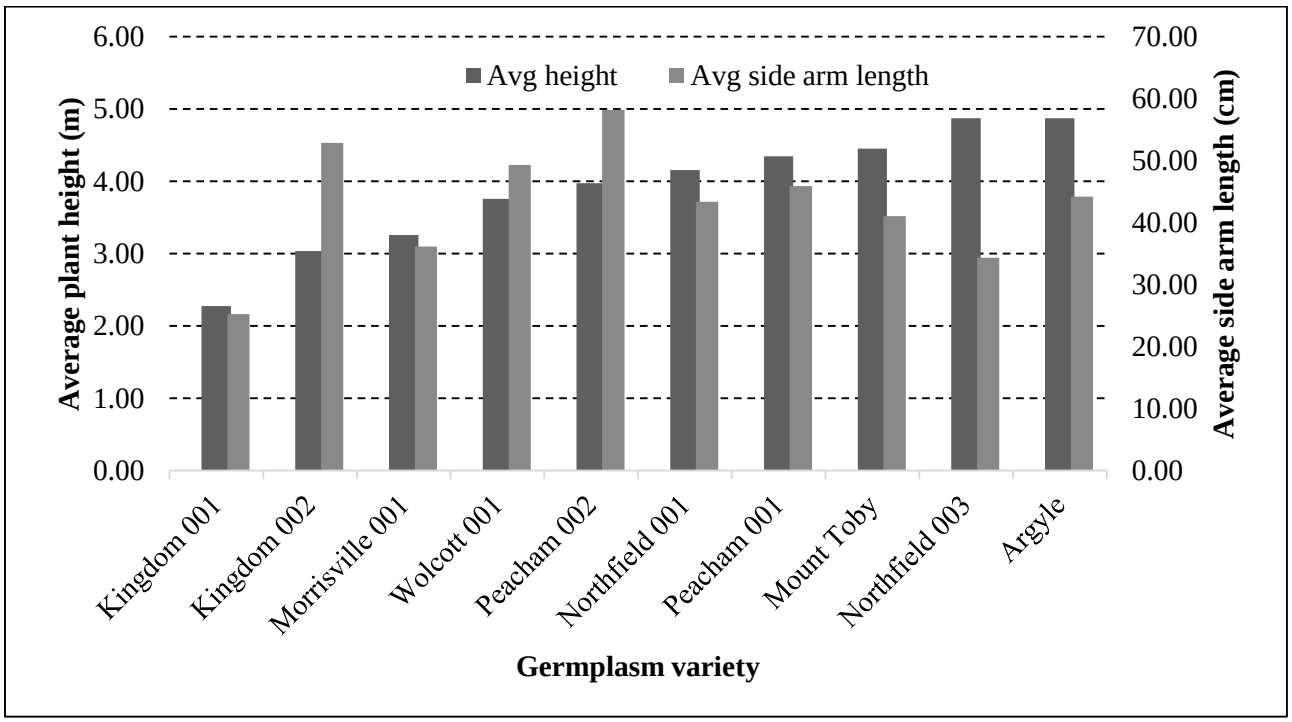

Figure 3. Average plant height (m) and average side arm length of germplasm lines, 2018.

Hop varieties also differed in yield and harvest characteristics (Figure 4, Table 2). This year due to harvester constraints, the germplasm varieties had to be harvested on the same date instead of during ideal harvest periods based on aroma and dry matter. The plant yields are also for first year plants as the germplasm was once again propagated and replanted into a new hopyard. With these factors taken into consideration, Mount Toby showed highest first year yields at 370 lbs ac^{-1} whereas Kingdom showed the lowest yields at 71 lbs ac^{-1}. Higher yields should be expected in subsequent years.

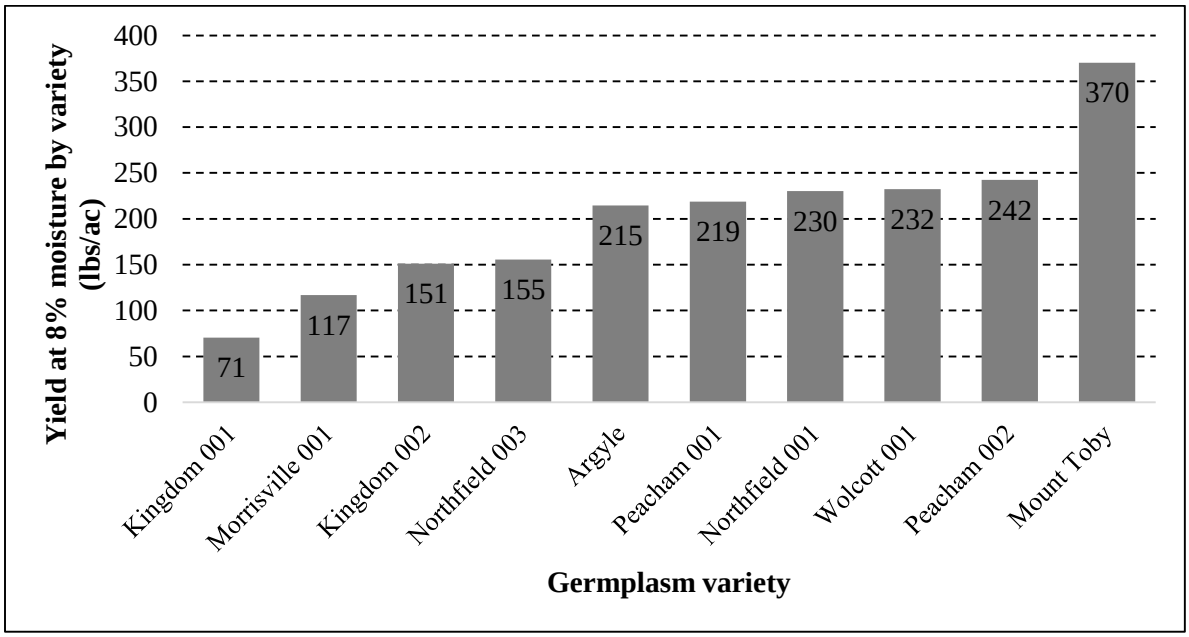

Figure 4. Yield of hop germplasm lines, 2018.

Table 2. 2018 Harvest characteristics by variety.

Variety	Harvest date	Yield @ 8% moisture lbs ac^{-1}	Harvest dry matter %	Cone disease severity 1-10†
Argyle	5-Sep	215	25.3	2
Kingdom 001	5-Sep	71.0	27.0	1
Kingdom 002	5-Sep	151	26.6	1
Morrisville 001	5-Sep	117	25.5	1
Northfield 001	5-Sep	230	26.4	2
Northfield 003	5-Sep	155	21.6	1
Peacham 001	5-Sep	219	25.1	2
Peacham 002	5-Sep	242	25.9	2
Mount Toby	5-Sep	370	24.6	3
Wolcott 001	5-Sep	232	25.4	4

†Cones were also rated in browning severity on a 1-10 scale where 1 indicates low browning and 10 indicates severe browning.

In 2018, disease pressure was very low resulting in less browning throughout each of the ten harvested germplasm varieties (Table 2). Despite having to harvest these wild hops at the same period, most fell within reasonable ranges if using dry matter as the sole means of determining harvest period.

Hop varieties varied dramatically in alpha and beta acids. In addition to varietal variability, hops also have potential to be influenced by various growing conditions such as fertility, temperatures, precipitation, disease pressure and many others, impacting their profiles.

Both Kingdom and Peacham samples showed some very close similarities this year in alpha and beta acids (Table 3). These two groups could be similar varieties as they were collected from similar areas, although genetic testing would need to be conducted to determine similarities or differences in the varieties.

Table 3. 2018 Wild hop variety brew quality.

Variety	Alpha %	Beta %	HSI
Argyle	7.90	5.50	0.36
Kingdom 001	15.9	5.50	0.30
Kingdom 002	15.1	5.10	0.28
Morrisville 001	8.80	5.90	0.28
Northfield 001	6.00	9.70	0.46
Northfield 003	3.90	7.10	0.49
Peacham 001	4.30	11.1	0.30
Peacham 002	4.90	11.2	0.16
Mount Toby	4.40	4.20	0.60
Wolcott 001	6.00	5.50	0.40

This year we were also forced to switch labs, adding another variable into the equation making it difficult to compare between years as processes differed slightly. In addition to the switch, samples molded while in posession of Alliance Analytical and samples were not able to be run accurately for essential oil profiles.

In addition to lab difficulties, hops had to all be harvested at the same time in 2018. In 2017, Wolcott 001 and Argyle were harvested on 7-Sep, whereas Northfield 001, Morrisville 001, and Peacham 001 were all harvested a week later on 15-Sep. In 2018, all varieties were havested on 5-Sep. In 2018, the hot and dry conditions from the season could have impacted the resin and oil profiles in addition to our necessity to harvest plants early this season. There is the potential that cones did not have the chance to fully develop resins or fully develop their essential oil profiles as a result of growing conditions or other circumstances. While we were able to have these samples analyzed for brew quality, samples did not have the chance to be accurately analyzed for essential oils and we were not able to compare these varieties with last years results.

DISCUSSION

As the project continues to develop, we hope to obtain additional wild hop samples from across the Northeast to build a database of genetically distinct cultivars of our wild hop species (*Humulus lupulus* var. *lupulus* and *Humulus lupulus* var. *lupuloides).* Wild hop varieties could provide new and distinct flavor profiles through variable acid and oil profile combinations for use by brewers. With the aim to build this database, new varieties could become available to regional hop producers that are more suitably adapted to our growing region through greater resistance to downy mildew and other prevalent and damaging pests and diseases. Furthermore, this could offer the potential to open up regionally adapted breeding experiments which could allow us to select hop traits that would be beneficial for our growing region. Ideally, this would lead to improvements in the quality and consistency of hops for our growers and brewers in our ever-expanding craft brewing industry in Vermont and the rest of the Northeast.

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